LIST OF TOPICS

	Preface	xiii
	Units and Notation	xv
	List of Symbols	xvii

BASIC LASER PHYSICS

Chapter 1 An Introduction to Lasers

1.1	What Is a Laser?	2
1.2	Atomic Energy Levels and Spontaneous Emission	6
1.3	Stimulated Atomic Transitions	18
1.4	Laser Amplification	30
1.5	Laser Pumping and Population Inversion	35
1.6	Laser Oscillation and Laser Cavity Modes	39
1.7	Laser Output-Beam Properties	49
1.8	A Few Practical Examples	60
1.9	Other Properties of Real Lasers	66
1.10	Historical Background of the Laser	74
1.11	Additional Problems for Chapter 1	76

Chapter 2 Stimulated Transitions: The Classical Oscillator Model

2.1	The Classical Electron Oscillator	80
2.2	Collisions and Dephasing Processes	89
2.3	More on Atomic Dynamics and Dephasing	97
2.4	Steady-State Response: The Atomic Susceptibility	102
2.5	Conversion to Real Atomic Transitions	110

Chapter 3 Electric Dipole Transitions in Real Atoms

3.1	Decay Rates and Transition Strengths in Real Atoms	118
3.2	Line Broadening Mechanisms in Real Atoms	126
3.3	Polarization Properties of Atomic Transitions	135
3.4	Tensor Susceptibilities	143
3.5	The "Factor of Three"	150
3.6	Degenerate Energy Levels and Degeneracy Factors	153
3.7	Inhomogeneous Line Broadening	157

Chapter 4 Atomic Rate Equations

4.1	Power Transfer From Signals to Atoms	176

4.2 Stimulated Transition Probability 181
4.3 Blackbody Radiation and Radiative Relaxation 187
4.4 Nonradiative Relaxation 195
4.5 Two-Level Rate Equations and Saturation 204
4.6 Multilevel Rate Equations 211

Chapter 5 The Rabi Frequency

5.1 Validity of the Rate Equation Model 221
5.2 Strong Signal Behavior: The Rabi Frequency 229

Chapter 6 Laser Pumping and Population Inversion

6.1 Steady-State Laser Pumping and Population Inversion 243
6.2 Laser Gain Saturation 252
6.3 Transient Laser Pumping 257

Chapter 7 Laser Amplification

7.1 Practical Aspects of Laser Amplifiers 264
7.2 Wave Propagation in an Atomic Medium 266
7.3 The Paraxial Wave Equation 276
7.4 Single-Pass Laser Amplification 279
7.5 Stimulated Transition Cross Sections 286
7.6 Saturation Intensities in Laser Materials 292
7.7 Homogeneous Saturation in Laser Amplifiers 297

Chapter 8 More On Laser Amplification

8.1 Transient Response of Laser Amplifiers 307
8.2 Spatial Hole Burning, and Standing-Wave Grating Effects 316
8.3 More on Laser Amplifier Saturation 323

Chapter 9 Linear Pulse Propagation

9.1 Phase and Group Velocities 331
9.2 The Parabolic Equation 339
9.3 Group Velocity Dispersion and Pulse Compression 343
9.4 Phase and Group Velocities in Resonant Atomic Media 351
9.5 Pulse Broadening and Gain Dispersion 356

Chapter 10 Nonlinear Optical Pulse Propagation

10.1 Pulse Amplification With Homogeneous Gain Saturation 362
10.2 Pulse Propagation in Nonlinear Dispersive Systems 375
10.3 The Nonlinear Schrödinger Equation 387
10.4 Nonlinear Pulse Broadening in Optical Fibers 388
10.5 Solitons in Optical Fibers 392

Chapter 11 Laser Mirrors and Regenerative Feedback

11.1 Laser Mirrors and Beam Splitters 398
11.2 Interferometers and Resonant Optical Cavities 408
11.3 Resonance Properties of Passive Optical Cavities 413

11.4 "Delta Notation" for Cavity Gains and Losses 428
11.5 Optical-Cavity Mode Frequencies 432
11.6 Regenerative Laser Amplification 440
11.7 Approaching Threshold: The Highly Regenerative Limit 447

Chapter 12 Fundamentals of Laser Oscillation

12.1 Oscillation Threshold Conditions 457
12.2 Oscillation Frequency and Frequency Pulling 462
12.3 Laser Output Power 473
12.4 The Large Output Coupling Case 485

Chapter 13 Oscillation Dynamics and Oscillation Threshold

13.1 Laser Oscillation Buildup 491
13.2 Derivation of the Cavity Rate Equation 497
13.3 Coupled Cavity and Atomic Rate Equations 505
13.4 The Laser Threshold Region 510
13.5 Multiple-Mirror Cavities and Etalon Effects 524
13.6 Unidirectional Ring-Laser Oscillators 532
13.7 Bistable Optical Systems 538
13.8 Amplified Spontaneous Emission and Mirrorless Lasers 547

OPTICAL BEAMS AND RESONATORS

Chapter 14 Optical Beams and Resonators: An Introduction

14.1 Transverse Modes in Optical Resonators 559
14.2 The Mathematics of Optical Resonator Modes 565
14.3 Build-Up and Oscillation of Optical Resonator Modes 569

Chapter 15 Ray Optics and Ray Matrices

15.1 Paraxial Optical Rays and Ray Matrices 581
15.2 Ray Propagation Through Cascaded Elements 593
15.3 Rays in Periodic Focusing Systems 599
15.4 Ray Optics With Misaligned Elements 607
15.5 Ray Matrices in Curved Ducts 614
15.6 Nonorthogonal Ray Matrices 616

Chapter 16 Wave Optics and Gaussian Beams

16.1 The Paraxial Wave Equation 626
16.2 Huygens' Integral 630
16.3 Gaussian Spherical Waves 637
16.4 Higher-Order Gaussian Modes 642
16.5 Complex-Argument Gaussian Modes 649
16.6 Gaussian Beam Propagation in Ducts 652
16.7 Numerical Beam Propagation Methods 656

Chapter 17 Physical Properties of Gaussian Beams

17.1 Gaussian Beam Propagation 663
17.2 Gaussian Beam Focusing 675
17.3 Lens Laws and Gaussian Mode Matching 680
17.4 Axial Phase Shift: The Guoy Effect 682
17.5 Higher-Order Gaussian Modes 685
17.6 Multimode Optical Beams 695

Chapter 18 Beam Perturbation and Diffraction

18.1 Grating Diffraction and Scattering Effects 698
18.2 Aberrated Laser Beams 706
18.3 Aperture Diffraction: Rectangular Apertures 712
18.4 Aperture Diffraction: Circular Apertures 727

Chapter 19 Stable Two-Mirror Resonators

19.1 Stable Gaussian Resonator Modes 744
19.2 Important Stable Resonator Types 750
19.3 Gaussian Transverse Mode Frequencies 761
19.4 Misalignment Effects in Stable Resonators 767
19.5 Gaussian Resonator Mode Losses 769

Chapter 20 Complex Paraxial Wave Optics

20.1 Huygens' Integral and *ABCD* Matrices 777
20.2 Gaussian Beams and *ABCD* Matrices 782
20.3 Gaussian Apertures and Complex *ABCD* Matrices 786
20.4 Complex Paraxial Optics 792
20.5 Complex Hermite-Gaussian Modes 798
20.6 Coordinate Scaling with Huygens' Integrals 805
20.7 Synthesis and Factorization of *ABCD* Matrices 811

Chapter 21 Generalized Paraxial Resonator Theory

21.1 Complex Paraxial Resonator Analysis 815
21.2 Real and Geometrically Stable Resonators 820
21.3 Real and Geometrically Unstable Resonators 822
21.4 Complex Stable and Unstable Resonators 828
21.5 Other General Properties of Paraxial Resonators 835
21.6 Multi-Element Stable Resonator Designs 841
21.7 Orthogonality Properties of Optical Resonator Modes 847

Chapter 22 Unstable Optical Resonators

22.1 Elementary Properties 858
22.2 Canonical Analysis for Unstable Resonators 867
22.3 Hard-Edged Unstable Resonators 874
22.4 Unstable Resonators: Experimental Results 884

Chapter 23 More on Unstable Resonators

23.1 Advanced Analyses of Unstable Resonators 891

23.2 Other Novel Unstable Resonator Designs 899
23.3 Variable-Reflectivity Unstable Resonators 913

LASER DYNAMICS AND ADVANCED TOPICS

Chapter 24 Laser Dynamics: The Laser Cavity Equations

24.1 Derivation of the Laser Cavity Equations 923
24.2 External Signal Sources 932
24.3 Coupled Cavity-Atom Equations 941
24.4 Alternative Formulations of the Laser Equations 944
24.5 Cavity and Atomic Rate Equations 949

Chapter 25 Laser Spiking and Mode Competition

25.1 Laser Spiking and Relaxation Oscillations 955
25.2 Laser Amplitude Modulation 971
25.3 Laser Frequency Modulation and Frequency Switching 980
25.4 Laser Mode Competition 992

Chapter 26 Laser Q-Switching

26.1 Laser Q-Switching: General Description 1004
26.2 Active Q-Switching: Rate-Equation Analysis 1008
26.3 Passive (Saturable Absorber) Q-Switching 1024
26.4 Repetitive Laser Q-Switching 1028
26.5 Mode Selection in Q-Switched Lasers 1034
26.6 Q-Switched Laser Applications 1039

Chapter 27 Active Laser Mode Coupling

27.1 Optical Signals: Time and Frequency Descriptions 1041
27.2 Mode-Locked Lasers: An Overview 1056
27.3 Time-Domain Analysis: Homogeneous Mode Locking 1061
27.4 Transient and Detuning Effects 1075
27.5 Frequency-Domain Analysis: Coupled Mode Equations 1087
27.6 The Modulator Polarization Term 1092
27.7 FM Laser Operation 1095

Chapter 28 Passive Mode Locking

28.1 Pulse Shortening in Saturable Absorbers 1104
28.2 Passive Mode Locking in Pulsed Lasers 1109
28.3 Passive Mode Locking in CW Lasers 1117

Chapter 29 Laser Injection Locking

29.1 Injection Locking of Oscillators 1130
29.2 Basic Injection Locking Analysis 1138
29.3 The Locked Oscillator Regime 1142
29.4 Solutions Outside the Locking Range 1148

29.5 Pulsed Injection Locking: A Phasor Description 1154
29.6 Applications: The Ring Laser Gyroscope 1162

Chapter 30 Hole Burning and Saturation Spectroscopy

30.1 Inhomogeneous Saturation and "Hole Burning" Effects 1171
30.2 Elementary Analysis of Inhomogeneous Hole Burning 1177
30.3 Saturation Absorption Spectroscopy 1184
30.4 Saturated Dispersion Effects 1192
30.5 Cross-Relaxation Effects 1195
30.6 Inhomogeneous Laser Oscillation: Lamb Dips 1199

Chapter 31 Magnetic-Dipole Transitions

31.1 Basic Properties of Magnetic-Dipole Transitions 1213
31.2 The Iodine Laser: A Magnetic-Dipole Laser Transition 1223
31.3 The Classical Magnetic Top Model 1228
31.4 The Bloch Equations 1236
31.5 Transverse Response: The AC Susceptibility 1243
31.6 Longitudinal Response: Rate Equation 1249
31.7 Large-Signal and Coherent-Transient Effects 1256

Index 1267